The wireless installation of R.M.S. *Titanic*

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ABSTRACT

The luxury steamship R.M.S. *Titanic*, the largest ocean-going passenger ship afloat at the time, sank on April 15, 1912, while on her maiden voyage, after striking an iceberg, resulting in the loss of over 1500 lives. But the fact that she was equipped with a (for the time) up-to-date wireless (radio) installation is credited with the saving of many lives, by bringing other ships fairly promptly to her aid.

This article reviews in detail many aspects of this installation.

In order to provide background for the discussion, the article includes introductions to pivotal technical aspects of the wireless transmitters of the era. An appendix compares and contrasts the wireless installation on *Titanic* with that of her sister ship, R.M.S. *Olympic*, the two installations being often confused.

1 CAVEAT

Various "facts" stated below are based on opinions of the author, based on his extensive analysis of the available information, and may differ from the positions of well-respected authorities.

2 THE ILL-FATED R.M.S. *TITANIC*

R.M.S. *Titanic* was a luxury steamship of the early 20th century, the pride of the fleet of the White Star Line. She sailed on her maiden voyage from Southampton, England, on April 10, 1912, with over 2200 passengers and crew aboard. She called at port at Cherbourg, France, and Queenstown, Ireland (now known as Cobh) before setting off across the Atlantic for New York, New York.

Late on April 14, 1912, traveling through the North Atlantic, she struck an iceberg, severely damaging her hull. She shortly went down, with the loss of over 1500 lives.

Titanic was equipped with an up-to-date (for the time) marine wireless (radio) system, with a powerful transmitter. Through the use of this, *Titanic* was able to summon aid from other ships nearby at the time, and several in fact rushed to her assistance. Most notable was R.M.S *Carpathia*, which, arriving almost two hours after *Titanic* had gone

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down, was able to rescue over 700 passengers and crew from the sea.

3 THE MARCONI OPERATION

3.1 Guglielmo Marconi and The Marconi Company

Guglielmo Giovanni Marconi (1874-1937) was an Italian inventor and engineer often called "the father of radio." He advanced and refined the concept of radio transmission into a constellation of practical systems, and founded and directed an industrial empire based on the commercial exploitation of this technology.

The wireless installation on *Titanic* was designed, built, installed and operated by what I will call for convenience "The Marconi Company"[1]. The equipment was owned by Marconi and leased to White Star Line. The two operators were not members of the ship's crew but rather employees of Marconi.

3.2 Architecture of the wireless installation

The radio installation was in three adjacent rooms on the centerline of the boat deck of *Titanic* (the uppermost enclosed deck), just aft of the officers' quarters and just aft of the foremost of the four funnels (stacks). The general location is shown by the red rectangle in Figure 1, adapted from a figure in from *Titanic–The Ship Magnificent* by Bruce Beveridge *et al* (by way of E*ncyclopedia Titanica*), and used here under the doctrine of fair use.

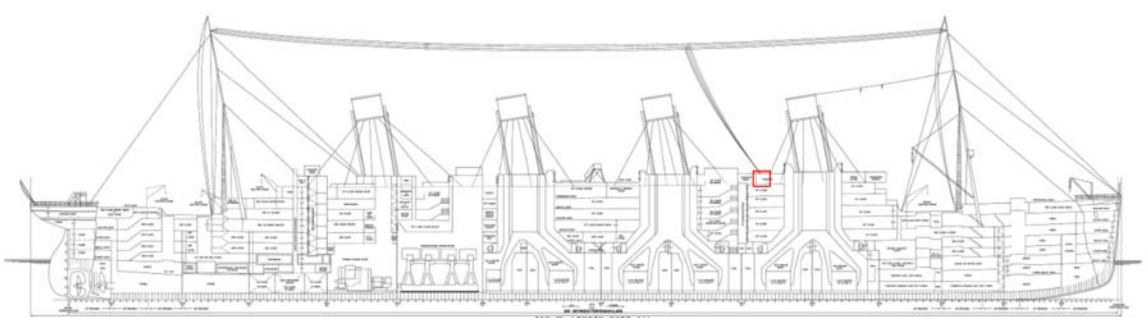

Figure 1. Side view of *Titanic*, showing location of the Marconi suite

In one, called the "silent room", which had sound-attenuating walls, were the "noisy components" of the radio transmitter: the motor-generator set and the rotary spark gap, as well as the other components of the transmitter proper.

The second room, celled the "Marconi room" was where the operators ran the radio system. It contained the telegraph key, two receivers,

[1] There were various companies involved, all with "Marconi" in their name, but I don't want to burden the text with that complication.

and the entirety of a small second transmitter, a backup for the main transmitter.

A third room (also adjacent) contained the bunks for the two operators.

Figure 2 shows the detailed layout as seen on a deck plan from the source mentioned above, and thought to be authentic.

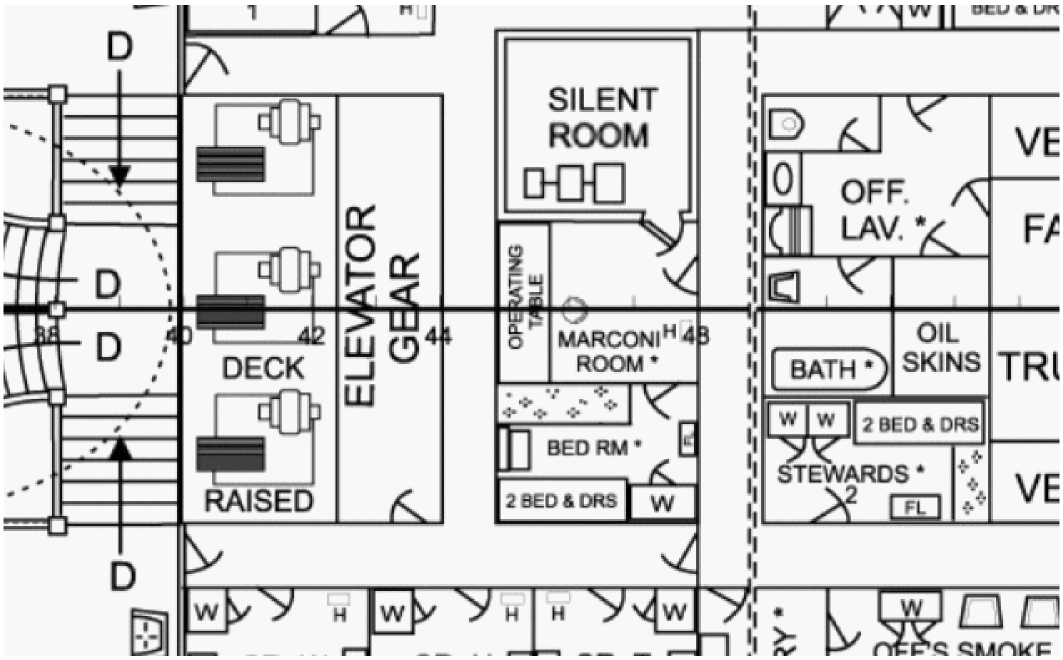

Figure 2. Floorplan of the Marconi suite

For scale reference, the numbered tickmarks along the centerline indicate hull frames, which in this part of the ship are on 36″ spacing. A little bush-league photogrammetry shows that, per this drawing, the Marconi room itself was approximately 9′5″ × 7′6″ in size.

3.3 The operators

With regard to the numerous ships having Marconi wireless installations, the operators were not permanently assigned to a particular ship. Rather, in general, they were assigned on a voyage basis (just like airline crew today). However, it seems that the two operators assigned to *Titanic* for her fateful maiden voyage worked with Marconi engineers and technicians in completing the installation on *Titanic*, just before she was due to sail.

3.4 Radiotelegraph traffic

The major traffic carried by the *Titanic* wireless facility was radio telegrams (often called "radiograms" or actually "Marconigrams"). These were messages between persons on the ship and persons on land (or maybe even on other ships). The cost of this service was substantial, but of course many passengers on Titanic were quite wealthy, and used the service liberally for the exchange of social messages. In addition, there were many "captains of industry" on board, and messages with their stockbrokers, lawyers, and factory managers were very common.

A second class of traffic was "company traffic", messages between the ship's master (and other officers) and the operational headquarters of the ship's operator, White Star Lines. This might typically include reports of the ship's progress on its voyage, orders for repair parts to be available at the next port to replace those taken from the ship's stock to make repairs enroute, and so forth.

A third class of traffic is "safety" traffic, which for example might include a report from another ship that it has encountered a field of heavy ice at its current position.

And of course the fourth kind of traffic is "emergency" traffic, such as a distress call from the ship seeking aid from other ships or shore facilities.

3.5 The "Father Browne" photo

Sadly for students of the *Titanic's* wireless system and its many details, it seems that there is only one known photo of the Marconi room on *Titanic*. It was taken by a Jesuit postulant, Francis Patrick Mary Browne.[2] He had booked passage on *Titanic*, on its maiden voyage, from Southampton, England to Queenstown, Ireland (today known as Cobh). It was of course fortunate for him (and us) that he debarked there rather than continuing on toward New York, which might well have cost him his life.

During an early part of the voyage, he went to the wireless room to send a radiotelegram.

While at the wireless room, he took a photo (perhaps while waiting for junior operator Harold Bride to finish his work and attend to him). Actually, he took two photos, unfortunately both on the same film frame.

So we are left with Father Browne's double exposure of Bride at work as the only known surviving picture of the *Titanic* wireless room. We see one of the many versions of it found on the Internet in figure 3.

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[2] Browne was ordained a priest in 1915, and it is the custom to refer to him today, regardless of the period of his life being discussed, as "Father Browne".

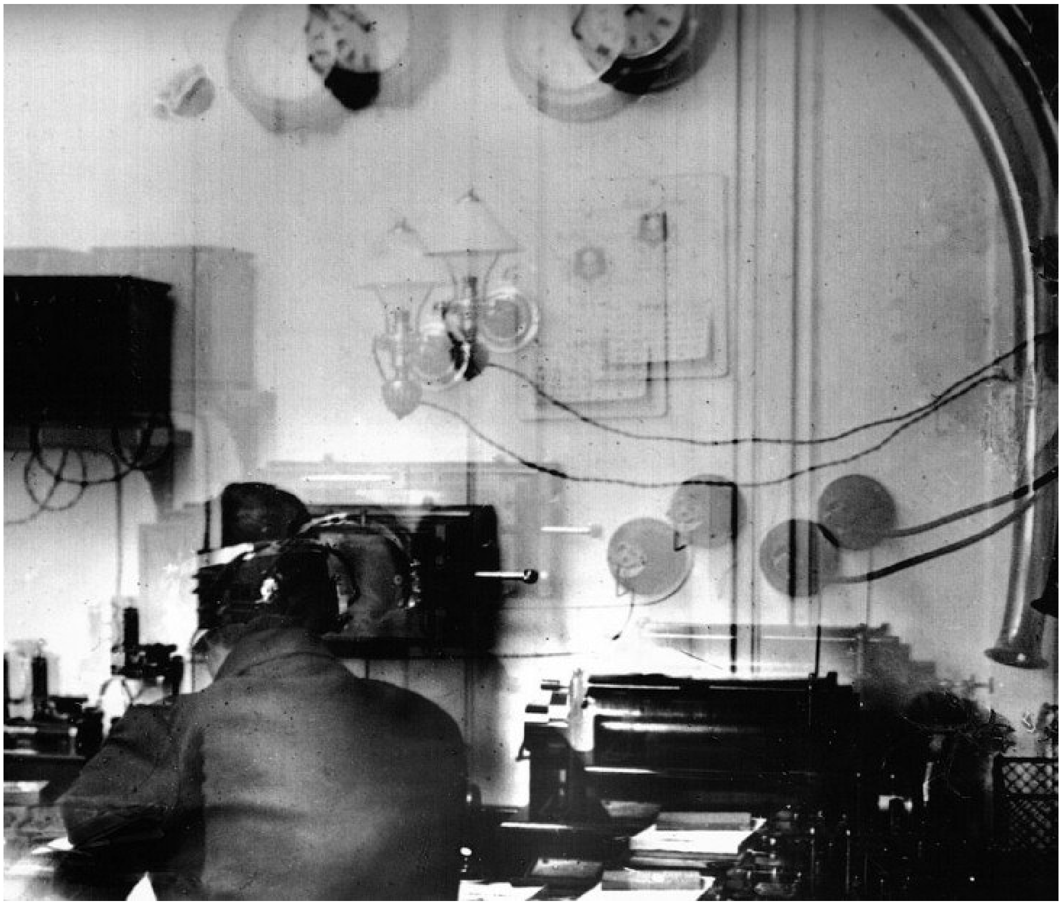

Figure 3. Operator Harold Bride in the *Titanic* wireless room
Photo by Francis Browne

4 INTRODUCTION TO SPARK WIRELESS TRANSMITTERS

4.1 Introduction

Prior to the development of the vacuum tube, the most widely used type of wireless (radio) transmitter used a spark through a spark gap as a critical element in generating a radio-frequency signal. And it was that type of transmitter that was used on *Titanic*, both as the main transmitter and for a smaller emergency transmitter. In this section, I will discuss the important principles of this class of transmitter.

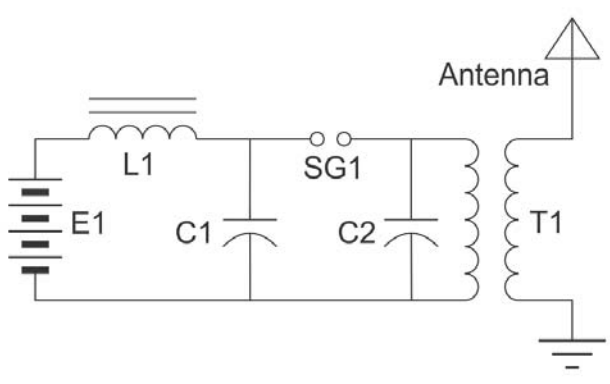

Figure 4. Simple spark gap transmitter

4.2 Basic principle

The basic principle of a spark transmitter can be seen in figure 4, which shows a schematic diagram of a simple form of this creature.

The high DC supply voltage E1 charges capacitor C1 through inductor L1[3]. When the voltage on C1 (and thus across spark gap SG1) reaches the "breakdown voltage" of the spark gap, a conductive arc forms across the spark gap. A significant amount of the energy from C1 passes, in a very short period, through that arc into the L-C resonant circuit made of capacitor C2 and the primary winding of RF (radio-frequency) transformer T1. That resonant circuit is tuned to the desired radio-frequency operating frequency of the transmitter.[4]

This energy pulse "excites" that resonant circuit, which oscillates at its resonant frequency. This is analogous to striking a gong with a hammer.

Inductor L1 allows the voltage across C1 to decrease as it discharges due to the current through SG1. Below a certain current value through SG1, the arc is extinguished. Then there is no ongoing path for the energy in the L-C circuit to flow back through the spark gap.

Therefore, most of the radio-frequency energy created by the oscillation in the L-C circuit goes to the antenna and is radiated as an electromagnetic wave (radio signal). Since there is (for the moment) no ongoing source of energy into the L-C system, the amplitude of this radio-frequency signal declines quickly—it is a "damped" wave. But before long capacitor C1 again charges to the breakdown voltage of the spark gap and the scenario repeats.

Figure 5 shows a typical waveform of such a signal.

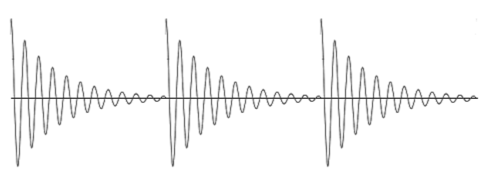

Figure 5. Damped wave

The rate of recurrence of the spark discharges (and thus the "bursts" of the waveform) varies widely over different transmitter designs, sometimes about 120 discharges/second, often in the range 500-1000 discharges/second, and in rare cases even higher.

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[3] Known "in the day" as a "choke coil", or just "choke".

[4] Ignored here is that the antenna itself has a gigantic effect on that resonant frequency

These transmitters were used for Morse code operation. The whole process I described above is started and stopped by the operator's telegraph key, by switching on and off the supply voltage to the transmitter circuit.[5]

Looked at from a theoretical standpoint, the signal applied to the antenna (and thus the resulting electromagnetic wave) can be thought of as a sine wave (a signal of a "pure" single frequency) modulated in its amplitude by a "waveform" that consists, repetitively, of a sudden rise followed by approximately an exponential decline.

Modulation theory teaches us that the resulting signal into the antenna (and thus the generated electromagnetic wave) does not consist only of a component at the resonant frequency of the L-C circuit, but in addition consists of powerful components separated from that frequency by multiples of the rate at which the spark gap fires, and at frequencies near those components. Thus the transmitted signal occupies a significant "bandwidth". As a result, it is impractical, within any frequency band, to simultaneously operate a large number of independent transmitters.

Often (especially once an alternative form emerged) this form of transmission was spoken of as "damped-wave" transmission.

4.3 AC operation

Of course, it is not that simple to provide a source of DC at a high enough voltage for this to work, so many serious transmitters (including those to be discussed in more detail here) instead operated on AC. Figure 6 shows a simple version of this.

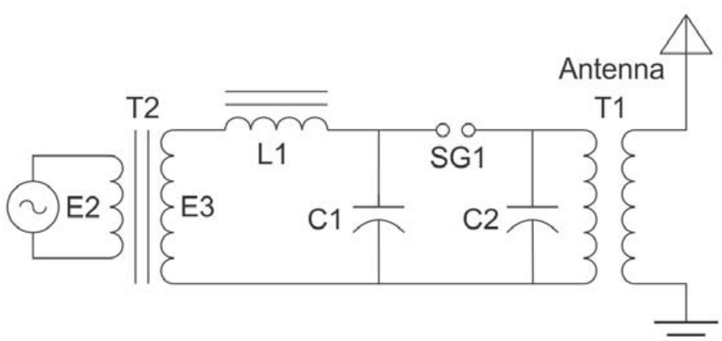

Figure 6. Simple AC-operated spark gap transmitter

The AC supply voltage, E2, is raised to a very high voltage, E3 (perhaps 10 kV RMS) by transformer T2. The rest of the operation is

[5] Perhaps this is actually done by a relay operated by the key, keeping high voltages and large currents away from the key..

essentially as described just above. Of course capacitor C1 can only charge to the voltage required for a spark to initiate when the instantaneous voltage of the AC is above a certain level. Accordingly, the spacing between "bursts" of the damped wave varies continuously, and there are periods in which no bursts occur.

4.4 The rotary discharger

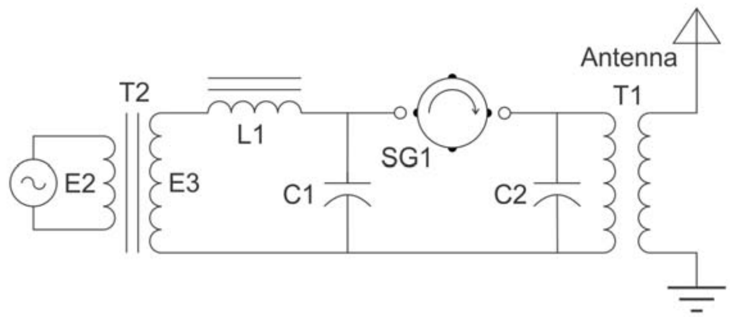

Figure 7. Rotary discharger spark gap transmitter

Operation of the transmitter can be made more consistent (and efficient) if we can force the spark gap to only discharge when the AC voltage is near its peak. One way to do this is to use a *rotary discharger* to provide the spark gap, Figure 7 shows this in simplified form.

The discharger typically consists of a rotating conducting disk with several conductive studs around its periphery. Two fixed electrodes are arranged so the tips of the studs pass close to them.

The rotation of the disk is synchronized with the AC supply waveform (the disk may for example be on the same shaft as the AC generator that creates the AC supply), and is adjusted in phase so the studs are near the electrodes when the AC wave is at its peak (positive and negative). Thus the two spark gaps in series (each between a stud and the adjacent fixed electrode) "fire" when the gap becomes small enough to no longer withstand the voltage at the time. And this of course happens at the peaks of the AC waveform.

If we make the rate of spark discharge in the range of perhaps 400-1500 Hz, the detected signal will have a "musical note" sound, assisting its clear reception. But that essentially requires that the frequency of the AC supply be at half that value, substantially higher than the 50-70 Hz we might otherwise expect to be used.

4.5 Frequency control

To help make the principle clear, in the descriptions above I implied that the frequency of the emitted signal was controlled by the resonant frequency of the circuit consisting of capacitor C1 and the inductance of the primary of transformer T1. But I lied. In fact, the operating frequency of the transmitter is the resonant frequency of the antenna system (sort of the tail wagging the dog). That is the natural resonant frequency of the antenna (determined by its dimensions), as we may modify that with external components.

We see this principle in figure 8. there is usually no capacitor C1, and there is an adjustable inductance in series with the antenna, as we see here:

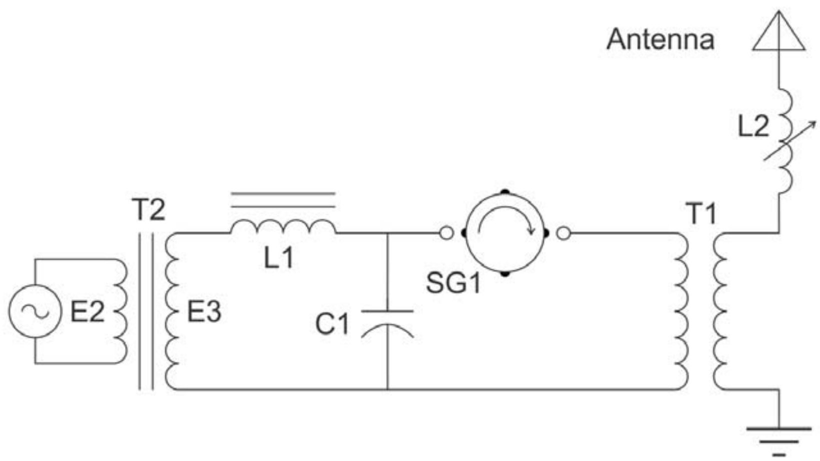

Figure 8. Rotary spark transmitter–more realistic

The natural resonant frequency of the antenna itself might not give us the operating frequency we want. So inductor L2 in effect changes the resonant frequency of the antenna (lowering it) to the frequency at which we want the transmitter to operate. We might say that the addition of this inductance apparels "lengthens" the antenna.

Amateur radio operators, mobile radio technicians, and others in the field will recognize this inductor as a "base loading coil". But in modern (*i.e.*, post "spark gap") work, the frequency of the transmitter is determined by an oscillator in the transmitter itself. Then the inclusion of the inductance lowers the apparent resonant frequency of the antenna to the operating frequency, making the antenna system more "willing" to accept the energy from the transmitter. (Here the dog wags the tail.)

4.6 Operation at higher frequencies

A spark transmitter may be called upon to operate at a frequency higher than the natural resonant frequency of its antenna. Just as we, for operation at a frequency lower than the natural resonant frequency of the antenna, make the antenna appear "longer" by the addition of inductance in series with the antenna (as we saw in figure 8), for operation at a higher frequency we can make the antenna appear "shorter" (thus having a higher resonant frequency) by the addition of series capacitance), as we see here:

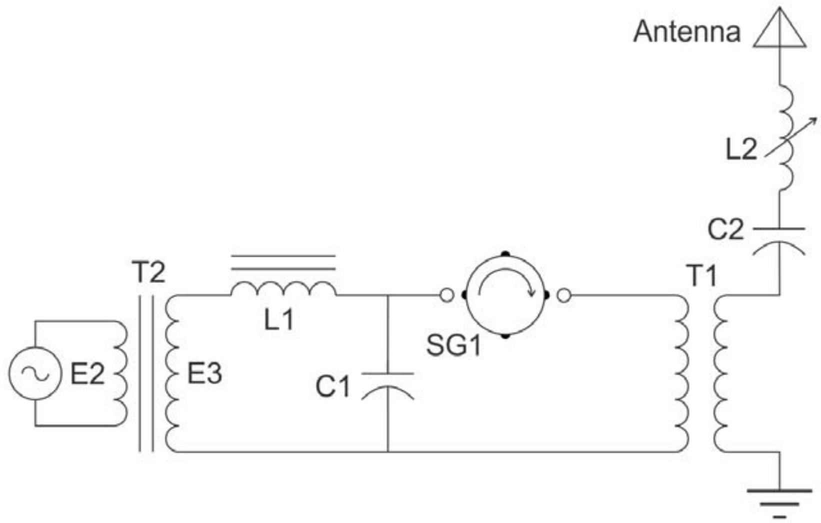

Figure 9. Operation at a higher frequency

As it was difficult to make variable capacitors with the properties needed in this circuit, a fixed capacitor was used, making the resonant frequency higher than ever needed (for the given frequency band). Then the familiar adjustable series inductor (L2) was again included to bring the resonant frequency down to just the needed value.

But there are various practical problems with implementing this circuit. Marconi himself realized that this circuit could be used to get the same result without those problems:

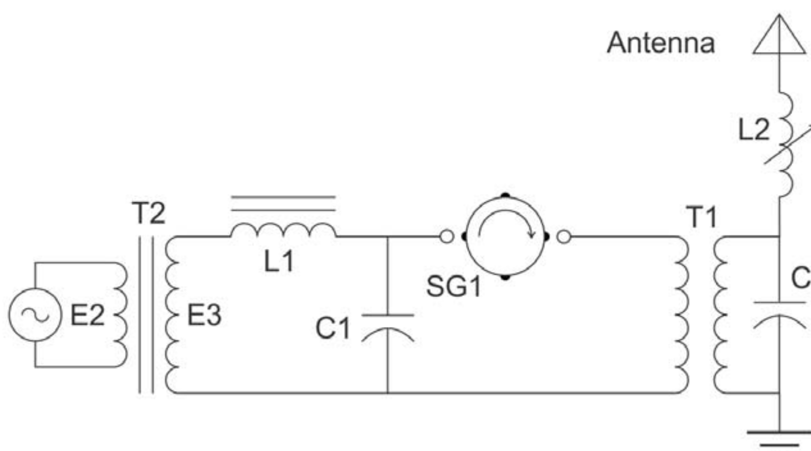

Figure 10. Alternate circuit for higher frequency operation

In either implementation, capacitor C2 was called the "short wave condenser" since it was used for operation at "short wave" frequencies (higher frequencies).

It is likely that the transmitter on *Titanic* had provision for a "short wave condenser" even though it does not appear on what we believe to be the wiring diagram for that transmitter.

4.7 In R.M.S. *Titanic*

The main transmitter of *Titanic* was of the rotary discharger type described in concept in section 4.4, but with a slightly different basic circuit, which we will see shortly. The AC supply, derived from the ship's 100 V DC distribution system by means of a DC-AC motor generator, was at a frequency of 420 Hz. The spark rate was 840 Hz.

5 THE OPERATING FREQUENCIES

At the time of *Titanic's* maiden voyage, the two frequencies authorized for maritime wireless operation were at a wavelength of 300 m (1 MHz) and 600 m (500 kHz).[6] The 600 m frequency was becoming the preferred one, but many ships (especially older, smaller ones) were equipped to use the 300 m frequency. The radio transmitter on *Titanic* could operate on either of those two frequencies. My understanding is that operation at the 600 m frequency was the most common.

6 THE TRANSMITTER CIRCUIT

Figure 11 shows a slightly-simplified version of what we believe to be the circuit of the transmitter on *Titanic*. It has been extracted from the wiring drawing we will see shortly as figure 12. It takes a somewhat different approach from the circuit we saw in figure 8. I'll describe the operation of the transmitter with reference to this drawing.

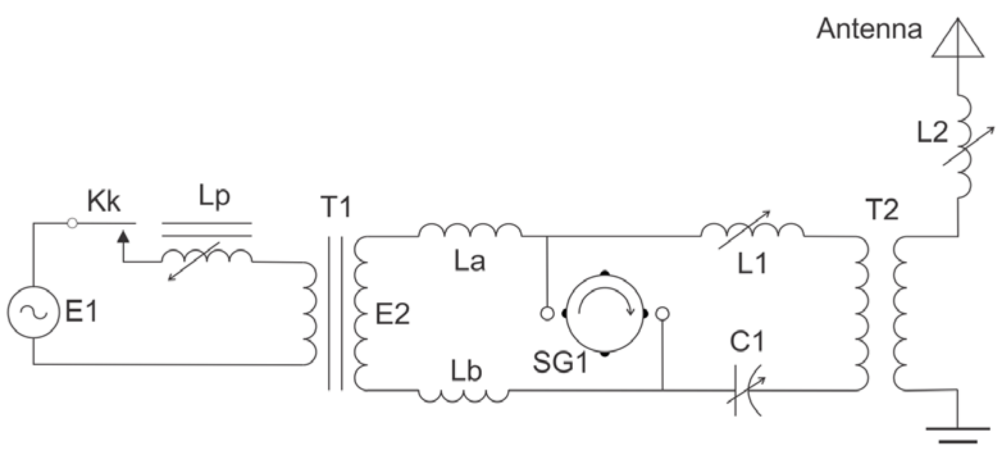

Figure 11. *Titanic* main transmitter circuit

E1 is the AC supply voltage (from the motor-generator set). Kk is the keying relay, operated from the key itself over a 100 V DC circuit (not shown here). Transformer T2 steps up the AC supply voltage to a high value, E2.

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[6] The regulation of radio operations was just emerging during the era of interest.

The AC to the transformer primary passes through primary inductor Lp, whose inductance can be changed by a switch working on taps on its winding. Its inductance is "reflected" through the transformer and, with the capacitance of C1 forms a circuit resonant at the AC frequency. This actually allows the charging of C1 at a greater rate than if Lp were not present, and to a higher voltage than otherwise.

The charging current passes through isolating inductors La and Lb, the HF primary tuning inductor L1, and the primary of RF transformer T1.

At the time the voltage on C1 nears its peak, a pair of studs on the rotor of the rotary discharger, SG (of course for "spark gap"), come near enough to the fixed electrodes that a pair of arcs (in series) are formed. These arcs have a very low effective resistance.

The forming of these conductive arcs causes a large pulse of current to flow from capacitor C1 through the arcs, HF primary tuning inductor L1, and the primary of RF transformer T2, leading to a pulse of voltage on the secondary of T2. The inductance of L1 can be changed to control the width of the pulse.

When the voltage across SG (with its conductive arcs) suddenly drops to a small value, the reactance of Lp (reflected through the AC transformer, T1) prevents an excessive current from being drawn from T1.

The voltage pulse from T2 "excites" a resonant system consisting of the antenna itself, the antenna tuning inductance L2, and the inductance of the secondary of T2 (Ls). That system "rings" (in a damped fashion) at its resonant frequency, and the antenna radiates a signal at that frequency. The various circuit elements (notably L2) have been adjusted by the operator so that this resonant frequency is the desired operating frequency of the transmitter.

Very soon, when most of the energy is discharged from C1, the arcs are extinguished. We might think that some of the RF energy in the oscillating resonant circuit would flow back through C1 and L1 and be absorbed in transformer T2. But the impedance of La and Lb at the RF frequency is high and this prevents any substantial RF current from flowing in that path.

Of course as soon as the arc is extinguished, the charging of C1 to ready it for its next performance begins anew.

7 THE PHYSICAL COMPONENTS

7.1 Introduction

Figure 12 shows what is believed to basically be the wiring of the model of Marconi transmitter used as the main transmitter on *Titanic*, as found on the Internet (the actual source being unknown to me). It is not a "schematic" diagram in that it doesn't use "schematic" symbols but rather pictorial presentations of the circuit items. I have added annotations for ease of reference (and they are consistent with the notation on figure 11, and have made a few other "improvements".

This diagram makes a nice pictorial "catalog of the animals".

In the description of the various components, I will sometimes repeat part of the description of their functions seen in section 6

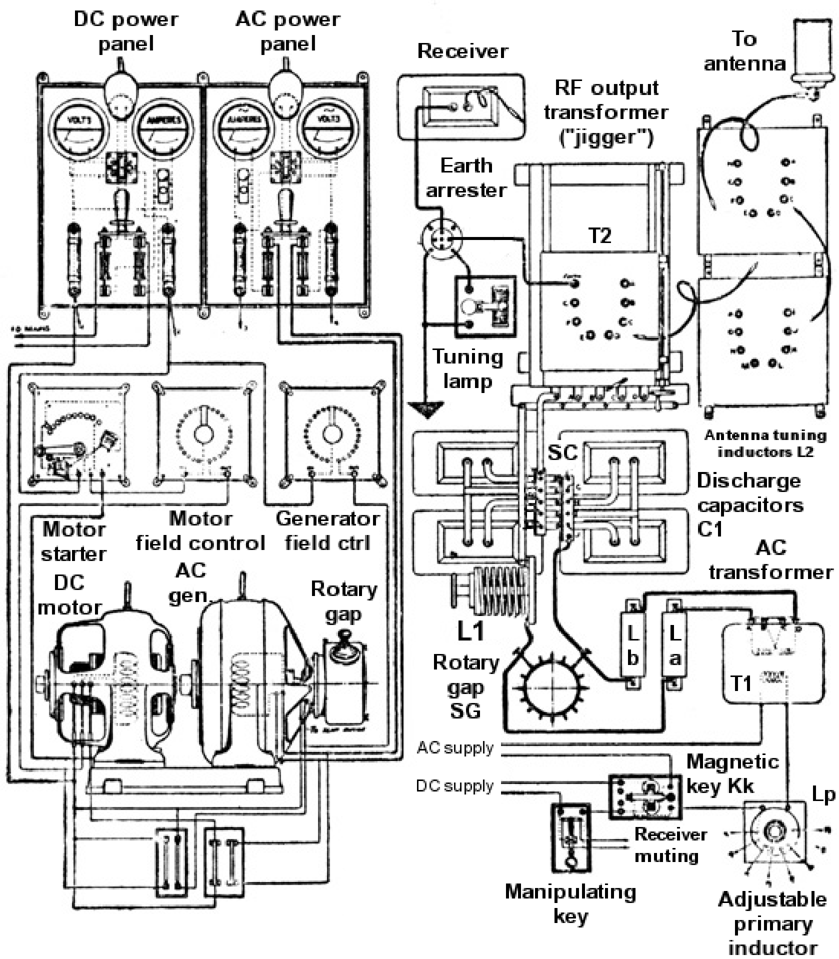

Figure 12. Wiring diagram of *Titanic* main transmitter

7.2 Physical location of the components

All the components described in the remainder of this major section, with the exception of the keying circuit (section 7.5) were located in the silent room, in part because some of them are rather noisy, most of the rest are quite bulky, and all were closely interconnected. For all practical purposes, the entire main transmitter is in that room.

7.3 The motor generator set and its controls

At the lower left we see the motor generator set, which operates from the ship's 100 V DC supply and generates AC at a voltage of about 300 V (the voltage is actually adjustable by the operator) and a frequency of 420 Hz (also actually adjustable by the operator). It had an output capacity of 5 kW.

The starter allows the operator, when starting the set, to at first apply the DC through a resistance to the motor, in order to avoid the dangerous effects of the extremely high current that would result if the full supply voltage were directly applied with the set at a standstill. As the set comes up to speed, the operator continues to move the handle of the starter, reducing the series resistance in steps, until, when the set reaches full speed, there is no longer any series resistance.

If the DC supply were to become interrupted, the motor-generator set would stop. Then if the supply returned, and if the starter handle were still in the "running" position, with no series resistance, the damaging current I mentioned before would occur.

To prevent this, the starter handle works against a spring tending to move it back to the "off" position. But when the operator has moved the handle fully to the "running" position at the end of the starting process, the handle is held there by an electromagnet, operated by the supply voltage.

Thus, if the supply voltage were to become interrupted, the starter handle would fly back to the "off" position. Then when the supply voltage returned, the operator would perform the starting operation from its beginning.

Two large rheostats allow the operator to vary the DC field current of the motor and the generator, independently. Varying the field current of the motor would change the speed of the motor, and thus the frequency of the generator. Varying the field current of the generator would change the output voltage of the generator.

We see on the right end of the motor-generator set the housing for the rotary discharger. In reality, it was enclosed by a wooden box with a layer of lead inside to help muffle the loud sound of the sparking of the discharger. There was also a layer of asbestos to prevent the sparks from setting fire to the box.

7.4 The power panels

At the upper left we see two power control panels, one for the incoming DC supply and one for the AC supply from the generator.

Each has a knife switch to connect or disconnect that supply, two fuses, and a voltmeter and ammeter.

7.5 The keying circuit

At the bottom, we see the operator's telegraph key. When it is down, it operates what we today would call a "keying relay" (Kk), which in turn completes the path from the generator (via the AC power panel) to the transmitter circuit proper. In the day, that "keying relay" was called a *magnetic key*, really quite apt as it was in effect an electromagnet-operated telegraph key.

Some AC-operated transmitters used a more sophisticated keying relay circuit. It used a clever principle to reduce the arc that would otherwise occur at the keying relay contacts when that relay opened the high-voltage, high-current circuit.[7] But this circuit was not usable when the AC frequency was as high as it was on *Titanic* (420 Hz). (The relay in that circuit was required to follow the half cycles of the AC current, not feasible at 420 Hz for relays with contacts of sufficient size.)

7.6 The primary inductance

The AC to the transformer primary passes through primary inductor, Lp, whose inductance can be changed by a switch working on taps on its winding. Its purpose was discussed in section 6.

7.7 The AC transformer

The AC transformer, T1, takes the perhaps 300 V AC fed to it and steps it up to something in the range of 15-20 kV. Its secondary winding is in two sections, which the operator can connect in series or in parallel, changing the voltage as needed for the frequency band in use (see section 9).

7.8 The isolating inductors

That output voltage feeds through two air-core isolating inductors, La and Lb. Their purpose was described in section 6.

7.9 The rotary discharger

Next we see, now in more symbolic form, the rotary discharger (labeled in the figure "rotary gap" owing to the lack of space), SG.

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[7] The reader who wants to know more about this will find it discussed at length in the companion article, "The wireless key of R.M.S. Titanic", by the same author, probably available where you got this.

The rotary discharger had 16 studs, and rotated once for each four cycles of the AC output of the generator. When properly aligned, just as the AC wave reached a peak (positive or negative), a stud came into alignment with each stationary electrode, leading to the formation of an arc at each. But each time the AC wave neared a “zero”, a stud also came into alignment with each stationary electrode. Of course, the voltage then being essentially zero, this did not precipitate the formation of arcs. Thus we might wonder why the 16, rather than 8, studs. Half of the studs would never participate in play.

The answer, I believe. is that the stationary electrodes were located so that when a stud of the “even set” neared one of them, a stud of the “odd” set neared the other. Thus each arc event resulted in one “even” stud and one “odd” stud being involved, thus distributing the wear caused by the arcing to be distributed over all 16 studs rather than over only 8, lengthening the life of the set of studs.

7.10 The discharge capacitors

Next we see an array of four capacitors (in the day called “condensers”). They will be assembled in series or parallel, to make up the discharge capacitor, corresponding to C1 in figure 11. These different capacitance values are needed for operation in the two frequency bands in which the transmitter can operate.

The two combinations are established by a set of horizontal and vertical brass bars that can be connected together by spring brass pegs inserted into holes in the bars at their intersections, called a *Swiss commutator* (and labeled SC in the annotated drawing).

The capacitors are physically very large, in tank-like metal housings.

7.11 The HF primary tuning inductor

Labeled L1 is the HF primary tuning inductor. (“HF” here means RF.) This is a spiral inductor in which one connection is made through a brush that can be moved, via a knob, along the length of the spiral, thus changing the inductance.

This inductance mainly controls the width of the pulse from capacitor C1 into the RF transformer, T2.

7.12 The RF transformer

Next in the circuit is the RF output transformer, T2, which is also part of the resonant circuit. This was called in the day the “jigger”.[8] Its secondary winding can be slid vertically (while the primary remains

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[8] The origin of that word is a mystery to me, and to many other authors as well. It was apparently introduced by Marconi himself in an early patent.

fixed), thus adjusting the coupling between primary and secondary as needed for proper operation. The movement is done with an elevator screw operated by a small crank (seen at the lower left of the unit).

The primary has a single turn of heavy copper strap, with several taps, the one to be used selected by a “plugboard” at the bottom of the unit. The secondary has 7 turns, accessed via 7 taps, any one of which can be chosen with a plug-ended jumper wire. These settings are all part of “tuning up” this wondrous instrument.

7.13 The antenna inductors

The *antenna tuning inductance*, L2 in figure 11, modifies the native resonant frequency of the antenna to the desired operating frequency. It is this “modified” resonant frequency that actually determines the frequency of the RF output.

This inductance is provided by the two inductors at the upper right (one or both of which can be put into the circuit depending on the band being used). Each inductor has 7 taps, any one of which can be connected to by way of plug-ended jumper wires.

7.14 The earth arrestor

The secondary of the RF transformer returns to ground (that is, to the ship’s iron hull) through a component called the “earth arrestor”. Its job is to change the overall system from the “receive” to the “send” mode whenever the key is depressed. The whole story is covered in detail in section 12. We note here the connection to the receiver(s) at this component.

7.15 The tuning lamp

For operation on any given frequency, the various adjustable components I spoke of above must be set to maximize the current into the antenna. Rather than using a hot-wire RF ammeter to observe the current, a less-costly indicator is used: a small lamp. We see it (actually a unit including the lamp) seemingly connected from ground to ground! But in fact the wire that seems to short-circuit the lamp unit is actually like an ammeter shunt (it has a finite, albeit small, resistance), allowing only a fraction of the total current to flow into the lamp unit.

To allow the sensitivity of the indicator lamp to be changed, on the lamp unit, in series with the lamp, is an adjustable inductor, adjusted with a sliding contact arm on the inductor coil itself.

7.16 Frequency control

Mentioned above but perhaps lost in the commotion is that the operating frequency of the transmitter is determined by the resonant frequency of the antenna circuit, which is a function of the resonant frequency of the antenna itself as modified by the antenna inductor. L2. Thus change in the operating frequency is primarily done by adjustment of the antenna inductor.

To allow the operator to ascertain when the desired frequency has been attained, a calibrated *wavemeter* was used. This had a tuned circuit whose resonant frequency could be varied with a precision variable capacitor; a calibration chart allowed the wavelength (frequency) to which the specific unit was then tuned to be determined.

The tuned circuit was followed by a "crystal" detector, whose output fed a telephone headset. The unit was tuned for maximum sound in the headset, and the wavelength then read from the calibration chart.

8 THE EMERGENCY TRANSMITTER

The wireless installations on *Titanic* included an emergency transmitter, which is self contained and almost wholly independent from the "main transmitter". It does, however, use the same large antenna as the main transmitter. To use it, the operator must switch that antenna from the main transmitter to the emergency transmitter by moving a "jumper wire" (I think located in the "silent room").

The transmitter had a rated power of 100 W, and operated from a 16 V storage battery. The battery was kept charged from the ship's 100 V DC power distribution system through a "charging control panel", on the operation of which I have no details. It was located in the Marconi room, on the wall adjacent to the silent room.

The high voltage need to operate the spark circuit was generated by an "induction coil" scheme in which a contact was repetitively broken by the magnetic field created in the primary coil, just as for the ignition coil in a Model T Ford. The secondary coil of this was in fact the inductor of the main resonant circuit.

Keying was done directly by the key contacts opening and closing the path from that 16 V DC source.

It is not known to me whether separate telegraph keys were in place for the main and emergency transmitters or whether a single key could switched to either..

To put the emergency transmitter into use, the operator disconnected a flexible lead, coming from the antenna where it entered the silent room, from the main transmitter and connected it a lead going into the Marconi room and there to the to the emergency transmitter. I'm not sure how the receivers fit into that picture.

We see a duplicate (or maybe replica) of the emergency transmitter in this photo of a nice replica of the *Titanic* Marconi room (figure 13).

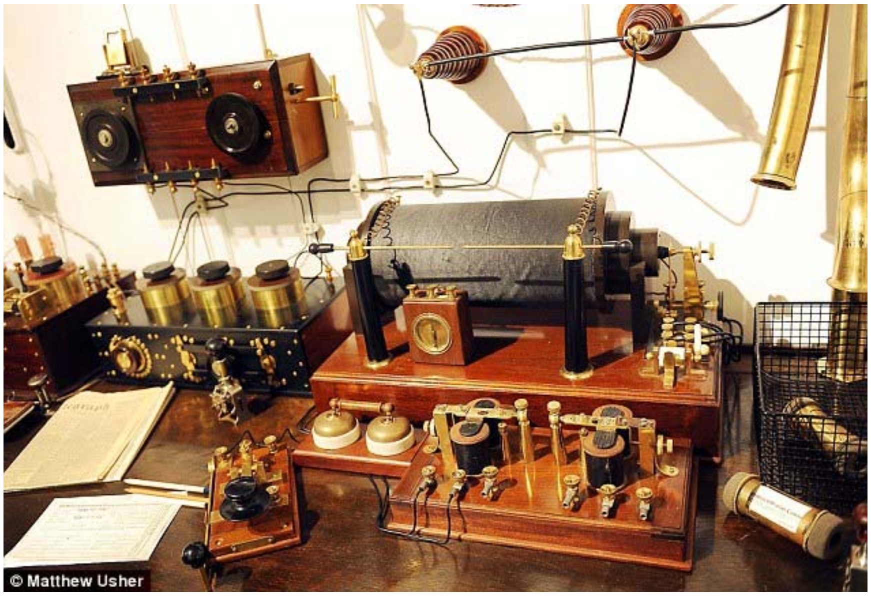

Figure 13. Replica wireless room

Interestingly enough, in this photo, we see only one key but nearby a pair of ganged switches (brass domed tops on white ceramic bases) that I suspect transferred the single key from the keying circuit of the main transmitter to that of the emergency transmitter.

We also see in this photo (in front of the emergency transmitter) a double magnetic key, used in the keying circuits of some transmitters. But, as I described earlier, that type of keying circuit was evidently not used on *Titanic*, the higher frequency of the AC supply precluding its use (and the circuit diagram we see as figure 12 does not show that circuit).

But I believe that this keying circuit **was** used for the transmitter used on *Titanic*'s sister ship. R.M.S. *Olympic*. And there is often confusion between the wireless installations on these two ships (not surprising since there are many photos of the *Olympic* installation and only one– badly blurred– for the *Titanic* installation).

But it's a beautiful replica, and its builder certainly deserves the benefit of some "artistic license".

9 OPERATION AT 300 METERS

We understand that most operation on *Titanic* was at the 600 m frequency (500 kHz), but the transmitter could operate at 300 m (1000 kHz).

Because even in this band the operating frequency was still lower than the natural resonant frequency of the antenna, it would seem that the circuit seen in figure 10 would not have to be used.

In any case, at this higher frequency, the antenna exhibited a greater impedance than at the lower frequency. In order to maintain the optimal transfer from the discharge capacitors into the RF transformer in this situation, the capacitors were charged to a higher voltage, but so that the total energy remained the same, a smaller capacitance was needed. Thus before commencing operation on the higher frequency band, the operator had to make some circuit rearrangements on the transmitter.

The capacitor charging voltage was doubled by changing the output windings of the AC transformer from parallel connection to serial connection; I do not know what sort of physical arrangement there was for that. It needed to be suitable for the voltage involved, which was on the order of 10 kV for each winding..

The discharge capacitance was then changed to one fourth its value by reconnecting the four capacitors from parallel connection to serial connection by moving the pegs on the Swiss commutator.

The formula for the energy stored in a capacitor is $E = \frac{1}{2} C V^{2,}$ where E is the stored energy (in joules), C is the capacitance (in farads), and V is the voltage (in volts). Thus we see that doubling the voltage while cutting the capacitance to one fourth maintains the amount of energy stored.

Since at this frequency the natural resonant frequency of the antenna is fairly near the desired operating frequency, we need to “lengthen” the antenna by far less that for operation at the lower frequency. Thus a lower value of the antenna inductance L2 is needed, likely requiring the use of only one of the two inductors.

10 THE RECEIVERS

10.1 Introduction

The *Titanic* was equipped with two receivers.[9] We see what are duplicates of them in Figure 14, which shows the pertinent part of a lovely replica of the *Titanic* Marconi room (I believe it is the same one seen in figure 13.

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[9] Some accounts suggest there was a third, of a different type yet from the two I describe here. I won’t pursue that further.

Figure 14. Duplicates of *Titanic's* receivers

10.2 The first receiver

The first receiver comprised two units. The first of these, the *tuner*, is the unit to the right on the operating desk with the three brass cylinders on its top. These are in fact very fancy variable capacitors. The tuner has three tuned stages and variable coupling between two of the stages. (One of the tuned "stages" is in fact the coupling link.) A ganged switch on the face allows the frequency range of the tuner to be switched over four bands (in one version on which I have information, that spanned the range of 80-2600 m wavelength). Another switch on the face allows switching among numerous taps on the antenna inductor, one aspect of tuning the rig to a certain frequency.

The actual tuner on the *Titanic* probably had on its top a knife switch that could be operated to bypass all but the of the first tuned circuits, putting the receiver into a broadly tuned state in the band to which the tuner was set. This was described as the "standby" mode, marked on the switch as "STAND BI"[10] With the tuner in this mode, the operator would hear any traffic on the band, and if it seemed as if a message was for his station, he could switch the tuner back to the normal position, "TUNE", and "tune it in".

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[10] The builder of this replica was lucky enough to find an almost-identical specimen, albeit the model without that switch.

The second part of this receiver was the detector[11]. We see it on the wall above the tuner. It looks a little bit like a reel-to-reel tape deck.

This detector, invented (or at least perfected) by Marconi used a very clever principle. A continuous loop of braided Iron wire, with a protective fabric jacket, moves continuously around the two wheels, one of which is driven by a clockwork motor, thus the T-handle winding key on the right.

The wire moves through a set of permanent magnets, which magnetizes it. It is then exposed to the AC field of a coil driven by the radio-frequency output of the tuner. That AC field will "demagnetize" the wire (just like the erase head of a tape recorder). Thus, the residual magnetism on the wire will have a profile that is inversely related to the variations in amplitude of the AC signal (which is the received RF signal). Then a second coil is excited by that residual magnetic field. Its output is the "demodulated" signal, and leads to the operator's headset.

We note that (if we exclude the mechanical energy put into the system by the winding of the spring motor) this system is entirely passive; there is no electrical feed to any part of it. For the most part, it all operates with the RF energy captured by the antenna. (I think a tiny bit of amplification may occur in the detector.)

This "magnetic detector" was, by the way, called by the operators "the Maggie".

10.3 The second receiver

The second receiver was in one unit. We see it to the left of the tuner of the first receiver.

Thus receiver also had three tuned stages and variable coupling. Again, the coupling link was one of the tuned stages.

Two of the stages were tuned by fancy variable capacitors of the type we saw on the first receiver's tuner. with cylindrical bases cases. The third (used to tune the coupling link) was of "trombone" construction. As before, the switch on the left of the face allows switching among numerous taps on the antenna inductor, one aspect of tuning the receiver to a certain frequency.

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[11] A *detector*, today often called a *demodulator*, takes a modulated radio frequency signal and extracts from it the modulation, which in this case would be the audible "hiss" of a less sophisticated spark transmitter or the musical tone of a rotary spark transmitter.

This receiver used a Fleming valve (the earliest vacuum tube, a diode) as its detector. The principle of its operation was the same as used in AM broadcast receivers for many decades.

There were in fact two tubes, connected in parallel, the purpose being to provide redundancy in case of failure of one of the tubes (the stated service life was 1000 hours). We see them in their cylindrical bulbs projecting upward from the rear of the top of the receiver.

This receiver is also “passive” in the sense that there is no amplification or such invoked, but it does require a source of 6 V DC to light the filaments of the Fleming valves. We see at the upper left of figure 14 two wooden cases. Each contains a 6 V storage battery.

To the left on the wall is a charging control panel, able to charge one of the batteries from the ship’s 100 V power distribution system. Each battery is provided with a long plug-ended cord. One battery is plugged into the receiver, and the other into the charging panel. They are interchanged periodically to keep this tooting.

11 THE ANTENNA

11.1 Physical design

The antenna of the *Titanic* (called an *aerial* in the day) was a *T antenna* developed by Marconi himself. It consisted of four parallel wires about 6.5 feet apart, strung between two wood spreaders at each end, which in turn were supported by “bridle ropes” from two tall masts about 600 feet apart. We can see the arrangement in figure 1.

Insulators were placed in each of the wires at the front spreader, and also at a point about midway between the third and fourth funnels. The “active” parts of the wires were 415 feet long.

A set of four feed wires, about 120 feet long, ran from the very centers of the active portion of the wires to a narrow boxlike wood *antenna trunk* atop the silent room, where they all connected to a single metal rod that ran down to the silent room. There a flexible wire led to the transmitter. We can see these feeder wires in figure 1.

11.2 Radiation from the antenna

In fact, in this antenna, the horizontal wires did not actually radiate very much. The radiation was mostly from the (nominally) vertical feeder wires. The horizontal wires provided capacitive loading to the vertical wires, increasing the current through them and making that current relatively high near the top (where the current would have gone to zero if we did not have the capacitive loading effect of the horizontal wires). Thus, more of the radiation emerged from a greater elevation than if the antenna only comprised the vertical wires, improving the potency of the transmitted signal.

Given that the set of feed wires is actually the radiating part of the antenna, it would in fact have been desirable for the downlead wires to actually be vertical, instead of at an angle as they were on *Titanic*. But various pragmatic conditions (like the location of the main stairway) precluded locating the Marconi suite where this would obtain.

11.3 Natural resonant frequency

We noted in section 7.13 that the resonant frequency of the antenna (as modified by the antenna tuning inductance and a few other things) determines the operating frequency of the transmitter. That inductance decreases the resonant frequency. (Alternatively, a capacitance could be added to increase the resonant frequency.)

But what does "natural resonant frequency" of an antenna mean? We ordinarily use that term to mean the frequency at which an antenna presents to the transmitter an impendence that is wholly resistive. That is the situation in which the antenna "most gladly" accepts power from the transmitter.

For an antenna that truly consists of a vertical wire or rod emerging from a grounded surface, the resonant frequency is very nearly that at which the length of the antenna is one quarter of the wavelength.[12]

In a Marconi T antenna, the horizontal conductors, by virtue of their capacitance to ground, "add length" to the vertical portion insofar as the resonant frequency is concerned. A handy rule of thumb for approximating the "effective length" of a T antenna is that the horizontal portion effectively adds one-third of its total length to the length of the vertical portion. That reckoning for the antenna on *Titanic* suggests that its natural resonant frequency was at about 950 kHz (a wavelength about 315 m).

Operation was most often in the 600 m band (500 kHz), for which the tuning inductor (L2) does the trick, For operation on the 300 m band (1000 kHz)[13] a capacitor (of fairly small value) is needed. We do not see it on figure 12, but it does appear on other drawings of Marconi transmitters of closely-related design..

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[12] More generally, at all odd multiples of that frequency, but we normally speak of that frequency.

[13] Spoken of at the time as the "short wave band".

12 SEND-RECEIVE CHANGEOVER

In many wireless installations there was a send-receive changeover switch. In the send position, this connected the antenna to the transmitter (and not the receiver, which would have been gravely overloaded, even damaged by the transmitter output voltage); enabled the transmitter so it could be keyed on; and disabled the receiver (or muted its output) so the operator wouldn't hear a raucous sound in the headset when the transmitter was keyed.

In the receive position, this connected the antenna to the receiver (and not to the transmitter, whose output impedance would have absorbed some of the signal the receiver wanted to hear); disabled the transmitter, so it couldn't be inadvertently keyed on; and enabled the receiver (or unmuted its output) so the operator could hear whatever the receiver received.

But in typical Marconi installations, and indeed in the installation on *Titanic*, what was essentially an automatic send-receive switch it revolved around, yes, another spark gap, this one very different from that used in the transmitter. This consisted of two metal plates with very flat surfaces facing each other, separated by a very small air gap–perhaps 0.01 inch (created by a very thin ring of insulating material around the outer edge of the upper disk). It is called an *earth arrestor* (a name I will explain a little later).[14]

The spark gap was placed in series with the connection to ground of the transmitter output, and the receiver input was connected across it, as we see in figure 15.

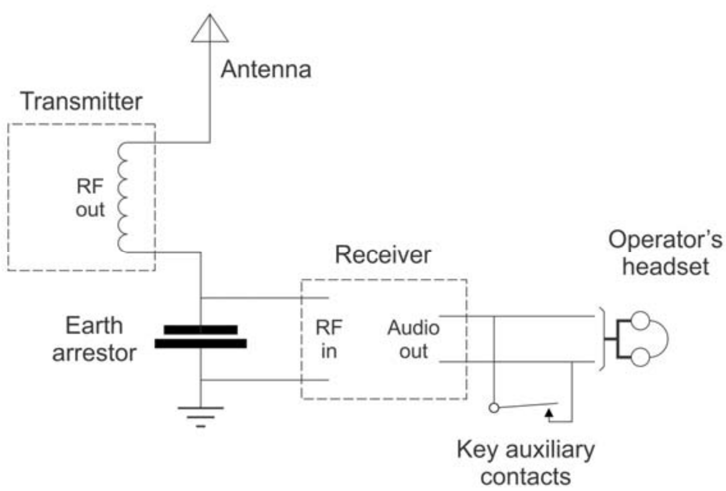

Figure 15. Earth arrestor circuit

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[14] Telephone engineers may be thinking, "This is just how protectors ("lightning arrestors" to civilians) originally used to work." Good thinking. Hold that thought.

The very small gap in the earth arrestor will break down with a very modest voltage. When the transmitter is keyed, its output voltage at first appears across the gap, which immediately breaks down. The arc across it has a very small voltage drop, and so from this point on, very little of the transmitter output voltage is lost across the gap. And of course the low voltage across the gap is small enough not to damage the receiver input circuits.

When the transmitter is not transmitting, the earth arrestor gap is not conducting, and the signal from the antenna travels through the output impedance of the idle transmitter (which is fairly low) to the receiver input.

But this leaves us with the problem of a raucous noise in the operators headset when the transmitter is keyed on (the voltage across the earth arrestor gap, and thus into the receiver input, is still pretty potent compared to a received signal).

This is taken care of in a rather direct way. The key used in an installation of this type has an auxiliary contact set. When the key is depressed, these contacts close before the actual transmitter keying contacts. When the key is released, these contacts do not open until the keying contacts have opened.

The auxiliary contacts short the circuit to the operator's headset, thus muting it during the time the transmitter is keyed on so the operator does not hear the raucous noise.

An advantage of this arrangement, versus the send-receive switch arrangement, is that in between the marks of the sent Morse code (*i.e.*, when the key was momentarily up), the operator could hear transmission from other stations. Then he could momentarily pause his sending to see if the other transmission was intended for his station.[15]

The name "earth arrestor" presumably comes from the fact that this special type of spark gap was essentially the same as was often used on wireless receiving installations to protect the receiver from large voltages that might appear on the antenna (such as from a nearby lightning strike). And in fact, in the *Titanic* installation, this unit actually provides that same protection to the receiver when the station is not transmitting. So here it earns its name via its "side job".

13 COMPARISON WITH THE OLYMPIC INSTALLATION

I mentioned earlier that the similarities between, but differences between, the Marconi wireless installations on the sister ships *Olympic*

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[15] Amateur radio operators will recognize this as "QSK" operation.

and *Titanic* have been the cause of many misunderstandings about the details of the installation on *Titanic*. In Appendix A, I review some of these differences, putting them in the context of a slightly longer evolution.

14 ISSUE RECORD

Issue 1 (this issue), October 19, 2018—Initial issue

15 ABOUT THE AUTHOR

Douglas A. Kerr is a retired telecommunication engineer. The earliest part of his professional career was with the now-dissolved Bell Telephone system, culminating with a five year tenure with Bell Telephone Laboratories. He was also for five years president of DeVry Institute of Technology at Dallas, an accredited for-profit engineering technology college.

While with Bell Laboratories, Doug was active in the development of ASCII by an industry committee, and was a principal author and editor of the standards document for first complete version of the code (1967). He also invented and held the patent on the caps lock key.

Later in his career, Doug operated his own consulting engineering practice, where a major activity was developing and teaching engineering seminars, some done through a major university but others done directly to telecom firms, telecom equipment manufacturers, and government agencies.

During that period Doug also from time to time gave expert testimony on telecom matters in civil suits and one criminal case.

Since his full retirement from professional practice, Doug has studied a wide range of topics and written over 125 technical articles on such diverse matters as the theory and practice of photographic exposure metering and the mechanisms of a reversible horse-drawn riding plow.

His only prior connection with *Titanic* is that when he and Carla were married (in 1999) she wore a dress closely modeled after the one worn by Kate Winslet as "Rose" in the 1997 movie, "Titanic".

Doug and Carla live now in Alamogordo, New Mexico, U.S.A., "where the desert meets the mountains".

16 ACKNOWLEDGMENTS

Many thanks to Tom Perera, W1TP, for his ongoing assistance and support as I struggled to unknot the various conundrums of this matter.

Thanks to Parks Stephenson, a “titan” of expertise on the *Titanic* overall, for his numerous fine articles on the wireless installation on *Titanic*.

Thanks to Fred Archibald, VE1FA, of the Halifax Amateur Radio Club, whose wonderful “slide show”, “Radio aboard the RMS Titanic”, was the source of much valuable information, in particular as to the frequency of the AC supply used by the main transmitter of *Titanic* and the details of *Titanic’s* antenna.

Special thanks to Carla Kerr for her insightful copy editing of an earlier draft of this difficult manuscript. But it has since taken on a bit of new material, so the responsibility for residual error is solely mine.

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Appendix A
TWO SHIPS, THREE TRANSMITTERS

A.1 Introduction

Here we will look into the rapid evolution in Marconi wireless installation design that led to the specific configuration used on R.M.S. *Titanic*, and we will see some of the differences of that configuration from the configuration used just a bit earlier on her sister ship, R.M.S. *Olympic*. As mentioned in the body of this article, the similarities and differences between the *Olympic* and *Titanic* configurations have led to a number of misconceptions about the *Titanic* installation.

A.2 The two ships

The two ships involved in this story are R.M.S *Olympic* and R.M.S *Titanic*. These were "sister ships", very similar in overall design (although *Titanic* was, as its name would seem to require, a little bit larger). *Olympic* was completed on May 31, 1911, and sailed on her maiden voyage on June 14, 1911. *Titanic* was completed on April 2, 1912, and sailed on her maiden (and last) voyage on April 10, 1912.

A.3 The three transmitters

Three Marconi spark transmitter designs are involved in this story.

A.3.1 The 1.5 kW plain spark transmitter

Both *Olympic* and *Titanic* were originally intended to be equipped with Marconi 1.5 kW "plain spark" (that is, not rotary spark) transmitters, using rotary converters[16] to provide the AC supply, at a frequency of 50-60 Hz. This was likely a design that had been used on quite a number of ships up to that point in time. As we will see shortly, it was not actually used on either *Olympic* or *Titanic*.

This transmitter design seemingly used a keying circuit in which the key itself actually **made** the AC current to the transmitter, but an auxiliary relay (called a *single magnetic key*) delayed the **breaking** of the circuit until the next occurring "zero" of the AC current waveform,

[16] A rotary converter of this type can be thought of as a DC motor and an AC generator, coalesced into a single unit, with a common armature and a common field and field winding. This leads to a rather more compact (and in fact, a bit more efficient) machine than a set with a distinct DC motor and AC generator. A disadvantage in this application is that it is difficult to separately adjust the speed of the machine (and thus the frequency of the AC output) and the voltage of the AC output.

avoiding the substantial arcing that would otherwise occur when the large transmitter current was broken at a random time.

A.3.2 The 5 kW plain spark transmitter

Not long before the completion of *Olympic*, a 5 kW Marconi plain spark transmitter became available, and it was decided to use it in Olympic. The increased power, of course, would provide for more reliable operation at longer ranges. I suspect that this transmitter used a rotary converter to provide the AC power.[17] Again the frequency of the AC supply was probably 50-60 Hz.

It is very likely that this transmitter used an advanced version of the keying circuit used in the transmitter described just above. This used an assembly of two relays (called a *double magnetic key*). In it, the key operated one of the relays over a low-current 100 V DC circuit. The contact on that relay then made the AC circuit to the transmitter, and the remainder of the operation (involving the second relay) was as described above for the single magnetic key circuit.

One advantage of this keying circuit was that the high AC voltage used by this transmitter (perhaps 300 V) did not appear on the key, which (since all the key parts were “open”) would have resulted in substantial hazard to the operator. It also meant that the key contacts did not have to be robust enough to make the large AC transmitter current (that requirement now being shifted to the first of the two relays).

In this transmitter design, many control components were located in the Marconi room (where the operator normally worked). The two power panels (DC and AC) were located there, as well as the three controls for the motor-generator set, all on the wall of the Marconi room adjacent to the silent room where, for example, the motor-generator set itself was located.

The tuning lamp, used to guide the tuning of the transmitter for most effective operation, was located on the Marconi room, not too handy given that the controls used for tuning the transmitter were all located in the silent room.

A.3.3 The 5 kW synchronous rotary spark transmitter

Shortly after, the Marconi 5 KW *synchronous rotary spark* transmitter became available, and it was decided to use it on *Titanic*. The synchronous rotary spark scheme provided more uniform output, was

[17] One respected authority on these matters reports that this transmitter used a motor-generator set rather than a rotary converter.

more efficient, and the "musical note" quality of the signal was known to provide improved reception.

This transmitter design also used a motor-generator set (rather than a rotary converter) to provide the AC power (especially desirable in this case since it allowed both the frequency and voltage of the output to be independently adjusted). Its output was typically 300 V, at 420 Hz, and thus the spark repetition rate was 840 Hz.

Because of the higher AC frequency here, neither of the keying circuits previously described could be used. (They both required a relay to follow the individual half cycles of the AC signal, and at 840 of those per second, no practical relay with sufficiently-substantial contacts could do that.)

Rather, it seems that here the keying circuit was a straightforward "keying relay" circuit. The key operated a relay[18] over a low-current 100 V DC circuit. The contact on that relay then keyed the AC to the transmitter, making and breaking the current whenever that fell.

There were a number of other subtle but significant circuit refinements in this transmitter design compared to that used on *Olympic*.

The power panels, motor-generator set controls, and even the tuning lamp, in Olympic mounted in the Marconi room, in *Titanic* were located in the silent room.

And still are.

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[18] I fear often also called a "single magnetic key", although it would have been quite different from the creature of that name mentioned earlier.