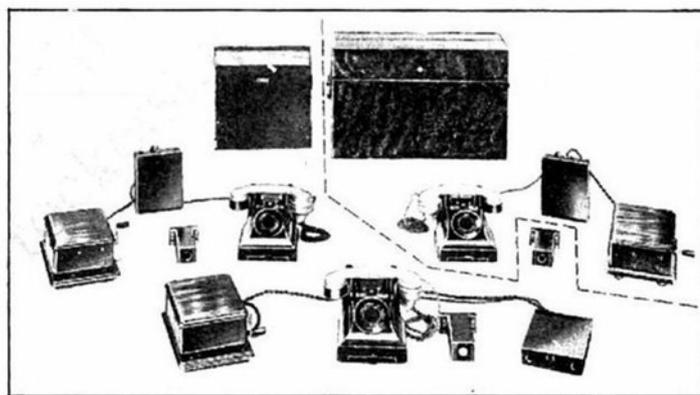# Scrambled

Andy Grant

Everything that you need to know about scramblers but were afraid to ask.

Scrambler System using SA5050

Whilst many collectors would have seen or maybe own a 300 series telephone instrument with a green handset described as a WWII 'scrambler', a lot of the information circulating about them varies wildly in accuracy. Little published information still exists about these devices as it was protected by the official secrets act for many years after they became obsolete and were taken out of service. I have spent countless hours researching the GPO scrambler system and present an as definitive as possible guide to the system and how it was utilised.

Early History

With the advent of the Second World War in 1939, the British war office requested the GPO research and development department to design 'equipment that will provide telephonic communication that is proof against casual or intentional eavesdropping'. The system that they developed was based on a valve (tube) based Frequency Changer mainframe that 'scrambled' the speech signal using a process based on ring modulation with a 2.5kc/s (kHz) carrier signal and demodulating the incoming signal from the distant end back to baseband speech. Various telephone instruments were con-

nected to these mainframes to be able to initiate and receive calls and to switch between clear and scrambled speech. An auxiliary unit was also available that enabled up to three telephone instruments to share one Frequency Changer mainframe and allow any of the users to 'hold' the mainframe unit for a forthcoming secure call and prevent the other users from using it at that time. This system started to be deployed through the war department network both at home and in the field from early 1940 and modified (four wire operation) Frequency Changers were built for use with radio communication. Tropicalised versions of the equipment were also manufactured for use in areas of high moisture or humidity. During WWII, the majority of this equipment was manufactured or assembled at the GPO's Holloway factory (code FH) but then in the post war period, much of this was moved to TMC and then later to other manufacturers also.

A Green Tele No.162 Type Scrambler Instrument on Winson Churchill's Desk, Circa Early 1940.

The Telephone Instruments

The first known scrambler installations of 1940 used green Tele No.162 type instruments for the scrambled conversation and a black Tele No.328 type instrument to estab-
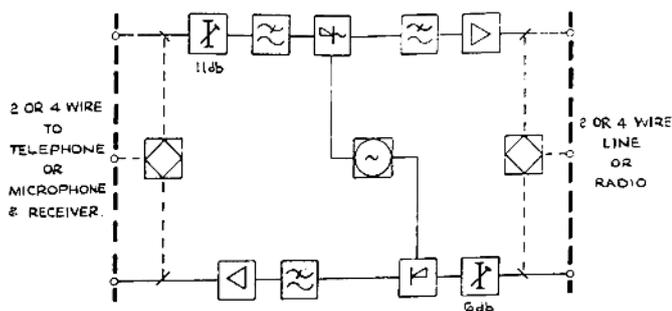

Tele No. SA5031

lish the call (un-scrambled) and then switch the line to the Frequency Changer and its dedicated scrambler telephone. It wasn't until later in 1940 that the more familiar 'combined set' was introduced. These telephone instruments functioned as standard telephone instruments in the NORMAL mode but when switched to SECRET, the internal transmission circuitry was bypassed and the telephone's transmitter and receiver were connected directly to the Frequency Changer which was in turn switched to the exchange line. In Local Battery installations, the battery was still used to provide current through the transmitter whereas in CB/Auto installations, the transmitter current was extracted from the exchange line using a filter circuit within the Frequency Changer mainframe. Whilst all looked similar at first glance, there were actually four variations of this telephone instrument:

SA5030

Introduced in August 1940 for use on CB/Auto Installations, this instrument consisted of a Tele.No.328 fitted with a Key No.303A switch assembly, Six (Seven if PBAX recall button fitted) way line cord with a BT20/8 and a Green 164 handset. A factory assembled SA5030 instrument is extremely rare as most of them were built by engineers in the field from locally available components and therefore most examples of these instruments are marked Tele No.328 on their base and chassis. The SA5030 was normally fitted with two push buttons and a label marked SECRET and NORMAL (later SCRAMBLE and NORMAL) but the centre button and the appropriate label could be fitted to provide a RECALL facility on PABX installations or for use with various extension plans.

Frequency Changer Principle of Operation

SA5031

Introduced in August 1940 for use on LB (C.B.S. 1,2&3) and Magneto systems, this instrument consisted of a Tele.No.394 fitted with a Key No.303A switch assembly, Eight way line cord with a BT20/8 and a Green 164 handset. A factory assembled SA5031 instrument is extremely rare as most of them were built by engineers in the field from locally available components and therefore most examples of these instruments are marked Tele No.394 on their base and chassis. Due to wartime shortages Tele No.396 chassis were sometimes used in these instruments also. The SA5031 was normally fitted with two push buttons and a label marked SECRET and NORMAL (later SCRAMBLE and NOR-MAL). A third button could be fitted in the centre position and the label changed accordingly for use with various extension plans.

SA5063 (SA5063/0)

Introduced in early 1943 for use on LB (C.B.S. 2&3) and Magneto systems (plus long lines on CB/Auto systems), this instrument consisted of a Tele.No.394 fitted with a Key No.303A switch assembly, 12 way line cord with a BT No.6 (20 way with metal lid) and a Green 164 handset. Due to wartime shortages Tele No.396 chassis's were sometimes used in these instruments also. The SA5063/0 was used either on a direct exchange/PBX line or with a SA5050 Auxiliary Unit to allow up to three SA5063 instruments to access a single Frequency Changer unit. The SA5063 was normally fitted with two push buttons and a label marked SECRET and ENGAGE FOR SECRET (later SCRAMBLE and HOLD SCRAM-BLER) but the ENGAGE FOR SECRET had no function if the instrument was connected to a direct exchange line. A third button could be fitted in the centre position and the label changed accordingly for use with various extension plans. Whilst the majority of SA5063/0s were factory assembled, they were also built by engineers in the field from locally available components and therefore some examples of these instruments can be marked Tele No.394 on their base and chassis.

SA5063/1

Introduced in February 1944 for use on LB (C.B.S. 2&3) and Magneto systems (plus long lines on CB/Auto systems), this instrument consisted of a modified Tele.No.394 fitted with a Key No.303B switch assembly, 12 way line cord with a BT No.6 (20 way with metal lid) and a Green 164 handset. Due to wartime

shortages Tele No.396 chassis's were sometimes used in these instruments also. The SA5063/1 was used either on a direct exchange/PBX line or with a SA5050 Auxiliary Unit to allow up to three sets of multiple SA5063/1 instruments wired in parallel to access a single Frequency Changer unit. The primary difference between the SA5063/0 and the SA5063/1 is that the latter had additional security switch contacts so that other instruments wired in parallel could not eavesdrop on a scrambled conversation. SA5063/1 were all factory made as the 394 chassis was modified and partially hard wired to the Key No.303B. The SA5063/1 was fitted with two push buttons and a label marked SECRET and ENGAGE FOR SECRET (later SCRAM-BLE and HOLD SCRAMBLER) but the ENGAGE FOR SECRET had no function if the instrument was connected to a direct exchange line. No third button could be fitted on these instruments as there were no spare switch contacts in the central position on the Key No.303B although there is record of later labels marked PRIVATE, NORMAL, ENGAGE FOR PRIVACY suggesting that a button was fitted in this position to release the other functions without having to replace the receiver.

The Frequency Changer Mainframes

There were several variations on the Frequency Changer (or 'Privacy Set' from 1951) mainframe dependant on their application and as technology advances were implemented:

Frequency Changer No. 6

This wooden cased unit was introduced in June 1940, operated on 200-250v AC or DC mains power and was designed to operate on CB/Auto installations only. This unit used CV1732 (Equivalent to ML4 or VT90/VT129) five pin triode valves (vacuum tubes) for signal processing and was short lived because of several design issues; the power for the telephone instrument was derived from the exchange line current which made it unsuitable for LB Installations and its ability to run on DC mains power meant that large parts of the chassis wiring was live and therefore potentially dangerous. This unit was superseded by the 6A/B/AA/AC versions within months.

Frequency Changer No. 6A

Introduced in August 1940, this CV1732 valve based unit had several design improvements over its predecessor including to be able to be set up for use in either CB/Auto or LB installations.

Frequency Changer No. 6AA

This unit would operate on 200-250v AC mains power only and had an isolated power transformer which improved safety for installation and maintenance engineers.

Frequency Changer No. 6B

Introduced in September 1940, this CV1732 valve based unit was similar to the 6A but had a power supply designed to operate on 200-250v AC or DC mains power and therefore had the live chassis associated with this. These units were only used in areas with DC mains but would also run on AC to allow for future updates to the mains supply.

Frequency Changer No. 6AA/0 and 6AA/1

Introduced in 1942, these metal cased units superseded the 6A for use on CB/Auto/LB installations and used later generation CV1052 (Equivalent to EL32 or VT52/VT180) octal based pentode valves with top cap first grid connections for signal processing. This difference between the /0 and /1 units were their mains power inputs: 200-250v AC (version /0) or 100-110v/200-250v AC (version /1).

Frequency Changer No 6AC.

Introduced in January 1944, this CV1052 valve based unit was similar the 6AA but had a power supply designed to run on either 100-110v/200-250v AC or 12v DC (via a vibrator circuit) for use in instances of mains power unavailability or failure.

Frequency Changer No. 6AC

Privacy Set No. 7/7A

Introduced in November 1957, this metal cased CV138 (Equivalent to EF91) B7G Pentode valve based unit for CB/Auto/LB installations used later generation technology offering better security and performance and modular construction for ease of maintenance. A more secure frequency inversion method in the transmit direction utilised two stages of modulation at 10.0705kc/s (kHz) and

Privacy Set No.7A

12.570kc/s (kHz) to minimise the risk of unscrambled speech reaching the line in the event of a fault. The Privacy Set No. 7A was designed to run on 100-110v/200-250v AC mains power whereas the Privacy Set No.7 was supplied without the mains power supply module to allow for other power options (including a 12v DC input module) to be fitted.

Tele No. SA5030 with Privacy Set No.8

Privacy Set No. 8/8A

A transistorised unit was for use on CB/Auto lines and was first mentioned in diagrams from 1962. This unit was fully compatible with the earlier valve based

Privacy Set No.9A

units and could be used with either the earlier SA5030 telephone instrument or a suitably configured Tele No. 710 or 740. There are variations on this unit's physical construction as it was built by several manufacturers. I have seen examples of these refurbished as late as 1977.

Privacy Set No. 9/9A

A transistorised unit similar to the Privacy Set No.8/8A but fitted with additional filtering (possibly to improve performance on poor quality lines). Privacy Set No.9 is first mentioned in diagrams from 1964.

System Options
Unit Auxiliary Apparatus SA5050

Introduced in March 1944, this relay set allows up to three SA5063/0 instruments or up to three sets of multiple SA5063/1 instruments wired in parallel to access a single Frequency Changer unit securely. Depressing the ENGAGE FOR SECRET (HOLD SCRAMBLER) button on one of the SA5063 instruments causes the SA5050 to prevent other instruments from connecting to the Frequency Changer for the duration of the call and will indicate this 'in use' status to other users via Indicators No.401CN mounted adjacent to the telephone instruments.

Provision of Frequency Changer facilities for Air Raid Shelters - Diagram SA5032

This diagram describes the sharing of a Frequency Changer between SA5030 telephone instruments located both in a normal position and in an Air Raid Shelter, using a Key No.289 and Key Mtg.NAA

Unit Auxiliary Apparatus SA5050

Indicator No.401CN

Frequently asked Scrambler questions
Why were some of the handsets painted green?

The wartime Scrambler instruments were manufactured at the GPO factory in Holloway and whilst their moulding plant was producing black telephone components in response to keep up with the increased demand at the time. Coloured handsets were not available from other suppliers and to stop their own moulding plant to change colour for a short run was impractical and so painting black handsets was the only practical viable option. Genuine painted handsets

1941 Oval on a Lime Green Painted Handset No.164

are almost always marked FH40/41/42 in the oval (but because of wartime supply shortages, some may have been sourced elsewhere). The paint colour was a lime green, not the jade green colour normally associated with moulded handsets. From 1943, the Holloway factory did produce small quantities of moulded green handsets (generally marked FH43/44/45) and they became more commonplace on post war instruments as peacetime manufacturing was resumed.

Why were many of the green handsets fitted with Black receiver caps?

The standard Handset No.164 manufactured during WWII were fitted with a Receiver No.1L, Diaphragm No.12 and Receiver Cap No.18 which were considered of insufficient quality to use with the scrambler system. An engineering instruction was therefore given that these should be exchanged for the higher performance Receiver No.2P, Diaphragm No.25 and Receiver Cap No.23 but these later design receiver caps were only available in black for much of the wartime period.

Were Scrambler Instruments ever fitted with Red handsets?

Photographs taken in WW2 bases, war rooms and bunkers have shown some Scrambler instruments fitted with Red

Wartime Command Area using Scrambler Instruments with Green, Ivory and Red Handsets

and Ivory handsets but I have found no official documentation giving any instruction or explanation as to why they should be fitted. I therefore surmise that the different coloured handsets were requisitioned and fitted locally to distinguish between instruments connected to different circuits.

Were Scrambler instruments ever fitted with Dials?

Tele. No. SA5030 was fitted with a dial when used on Auto exchange or PABX lines. Tele No. SA5031 and SA5063/0 and /1 were normally fitted with dial blanking plates as they were primarily designed to be used on Local Battery/Magneto Exchange or PBX lines but they could all be fitted with a dial for long Auto line working if required.

Why are Local Battery Scrambler Instruments more commonplace than CB or Automatic ones?

The very early scrambler sets were used on the public network but the War Office quickly established its own network independent of the public exchanges which was predominantly Local Battery and manually switched. This is why the vast majority of the scrambler telephone instruments that have survived from this period are of the Local Battery type and are not fitted with dials. The SA5030 CB/Auto Instrument was only used where there was no other option but to connect via the public network in CB/Auto areas.

Why is there often a 'Speech On Telephone Is Not Secret' label on the dial blanking plate?

Contrary to popular belief, these labels were not actually intended to be affixed to Scrambler Telephone Instruments. They were only ever meant to be affixed to other telephone instruments in the vicinity of Scrambler Instruments to indicate that conversations undertaken on them were not scrambled but in reality, they were stuck to everything!

A 'Speech On This Telephone Is Not Secret' Label in the Wrong Place.

Were all Scrambler Instruments fitted with 12 way line cords and the 20 way Block Terminal No.6?

Whilst Tele No. SA5063/0 and /1 were fitted with this line cord and Block Terminal combination, Tele No. SA5030 was fitted with a 7 or 8 way line cord, Tele No. SA5031 was fitted with an 8 way line cord and both of these terminated on a standard Block Terminal 20/8.

What were Frequency Changers No.4 and No.5?

These devices were introduced in 1939 but were never designed for scrambling speech. Their function was to derive 75v 100Hz AC switching pulses from a 50Hz AC mains supply 'for relay control over P.O. Lines'

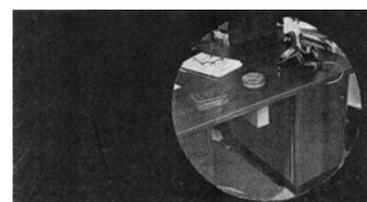***Was the Scrambler system ever made available outside of the Military or Government?***

Restored Clear TMC 'Secraphone' Scrambler Demonstration Set

From the late 50s, the GPO made the scrambler system available to commercial customers in the form of an SA5030 telephone instrument coupled with a Privacy Set No.7, 8 or 9. This system was available into the late 70s but with the SA5030 superseded by a suitably configured Tele No.710 or 740. TMC also sold these versions of the system to their business customers branded as 'Secraphone'.

Reference Sources.

The vast majority of the information in this article has been obtained from documentation from my personal collection including GPO Diagrams and Engineering Instructions and War Office archive documentation. I would also like to thank Keith Wheeler, Laurence Rudolf and Andrew Emmerson for their kind assistance in providing invaluable additional information.

Photo acknowledgements: BT Archive, Connected Earth, Paul Grafton, Andy Grant Collection. Whilst I have tried to make this article as comprehensive and accurate as possible there is always the possibility of errors or omissions so I would be pleased to hear from anyone that has any additional information on the areas covered.

TMC Secraphone Brochure