

The Movie Star and the Secret Weapon.....

How about this for a movie script; an actress flees her homeland after it is taken over by a murderous dictatorship, and settles in the United States. Within a few years she is well known for her films, but has also invented a secret communications method for her adopted homeland.

Far fetched? Well, I thought so too until I learnt about Hedy Lamarr and her invention of Spread Spectrum technology. In this article I'll tell the story of how the team of this glamorous icon of the 1940s and her musical director came up with a technology that is widely used today in cellular phones and many other communication systems.

Hedwig to Hedy

Hedy Lamarr was born Hedwig Eva Maria Kiesler on September 11, 1913 in the city of Vienna, Austria, at the time part of the Austro-Hungarian empire. She married an industrialist called Fritz Mandl, and from him this highly intelligent young woman picked up a lot of information and gossip about the armaments industry with which he was involved in. Unlike her husband, who became enamoured of the Nazi party, Hedwig, who'd already started doing some acting, left for London and then went on to Hollywood to take up acting. A swift name change soon followed, and Hedy Lamarr was born. She had starred in some rather 'risqué' movies, particularly 'Ecstasy', by the time that she and her musical arranger, George Antheil found themselves at a dinner party one evening in 1940 thinking about the unfolding European war.

Guided Weapons

The United States, then neutral, was developing a number of weapons that depended upon radio signals for guidance. Amongst these was a guided torpedo, which could be steered towards its target by a radio signal. However, there was a problem; any radio guided missile had a weak link in that given adequate warning that such missiles were in use Nazi scientists could easily produce a radio receiver that could be used by prospective targets to detect the signals used to control the missile or torpedo and then a transmitter could be used to jam the guidance system. Indeed, the jamming signal could be very simple; it might be enough to tune a transmitter to the signal frequency and just turn it on. As the missile approached the target the controlling signal would be weakening with distance from the guiding plane or ship,

while the jamming signal on the target would get stronger. Eventually it would overwhelm the guidance signal with the effect that the missile would effectively become a 'dumb' weapon and simply carry on in a straight line past the target.

Frequency Hopping

So, what could you do? Hedy was a smart cookie, as they say; she quickly realised that if it were possible for the guidance signal to randomly change frequency it would be difficult for the enemy to actually detect the signal in the first place, and virtually impossible for them to then transmit a jamming signal that would follow the guidance signal. This 'frequency hopping' would need to be random and fairly frequent (Figure 1) to prevent the enemy predicting which frequency would be used next. Changing the frequency of the transmitted signal on such a basis would be reasonably straight forward to achieve; what was more difficult, Lamarr realised, was making sure that the receiver on the missile or torpedo was able to synchronise itself with the transmitted signal so that as the transmitter changed frequency the receiver would change its receive frequency at the same time. Don't forget, by the way, that this was before the invention of the transistor; all radio communications depended upon valves, and the computer, even in its most rudimentary form, would not appear until 3 years later and would then occupy a whole room...not the stuff you could fit in the head of a torpedo no more than two feet in diameter.

Player piano

The composer George Antheil was a friend and colleague of Lamarr's, and due in part to his background as a composer he imagined that one possible solution to the problem of synchronising transmitter and receiver would be to incorporate some sort of switching mechanism into the transmitter and receiver that could read a 'tape' of instructions, a little like the punched paper strips read by automatic 'player pianos'. These machines read cards or paper tape similar to what would be later used to program computers, and as the tape was 'read' through the machine the holes in the tape caused musical notes to be played. Analogously, thought Antheil, it should be possible for the tape in the transmitter to switch the transmitted frequency as it was slowly unwound through some sort of electronic switch capable of detecting holes in the tape, and similarly an identical tape in the receiver should be able to switch receiver circuits to different frequencies for signal reception (Figure 2). If you

had two identical tapes, unwound at the same rate, one in the transmitter and one in the receiver, you could synchronise the transmitter and receiver to stay in step with each other. Of course, any mechanical system is prone to slippage and slight losses of synchronisation, but the principle was there. In December 1940, the concept of a communication system based upon 'frequency hopping' was submitted by Hedy Lamarr and George Antheil to the National Inventors Council, a US Government organisation that was co-ordinating technical developments for the war effort. The patent, number 2,292,387 was eventually filed on June 10th 1941 and was granted over a year later in August 1942, when the Britain, the US and the USSR were up to their necks in the series of defeats that would only be halted at El Alamein and Stalingrad. Now would be a very good time for a secret weapon to be developed.....

The Practicalities

Unfortunately, the practicalities of setting this up would prove to be too difficult; the synchronising tapes would have had to be paper tapes, and the whole technical issue of putting fairly complex electronics and mechanics in to the small and rough environment of a bomb or torpedo was too much. Lamarr and Antheil gave their Patent to the US Government as part of the war effort, but their creation would have to wait for almost 20 years until the invention of the transistor and other semiconductor devices allowed the construction of practical, if crude, frequency hopping equipment that was based around digital circuits that created a reproducible, but apparently random, string of random electronic impulses that could switch circuitry with no moving parts.

Practical Uses

The patent lapsed in the early 1960s, at the heart of the cold war, and the US Navy immediately put the system to use using semiconductor technology to create a frequency hopping secure communications system. This was the start of the military use of 'spread spectrum' technology, the direct descendant of the Lamarr's invention. The technology would soon find itself used in a wide range of military communication systems, with frequency switching taking place many times a second making it difficult for an enemy to even detect a signal; a spread spectrum signal heard on a 'normal' radio receiver just sounds like a slightly higher than usual level of noise on the channel. This is shown diagrammatically in Figure 4. The technology was eventually de-classified in the 1980s, just in time for the technology to be

used in cellular telephone systems. To see why this technology is useful one has to consider that a lot of cellular phones are in use in the same geographical area. It's not really feasible for a given phone to be given its own frequency, as there just aren't enough frequencies. Instead, cellular phones can transmit on a number of frequencies and the frequency in use will 'switch' as the phone call is made and the user moves from one 'cell' on the cellular network to another. The switching from frequency to frequency also reduces the effect of interference on the signal; an interfering signal that is strong on one frequency may be quite weak on another, and so although some of the signal may be lost there is a greater chance for the signal to 'get through'.

In addition to the cellular phone, low level spread spectrum transmitters are used in 'wireless' computer networks, where data is sent from portable computers to other computers by UHF or microwave radio signals. Again, single frequencies would not be feasible in a busy office environment or city centre, so the network adapters that allow the computers to talk to one another use spread spectrum techniques to improve reliability and data security; unless you know a lot about the network it's quite hard to listen in and detect computer traffic on wireless networks due to the frequency hopping.

The algorithms used to control the frequency hopping in different spread spectrum systems are quite varied, depending upon the job in hand. For example, cellular phones and wireless network cards use chips that generate a pseudo random string of pulses. Two devices in communication will initiate the session by exchanging enough information to set the 'start' position for the random pulse chain. Provided the two systems start from the same place, they'll keep in synchrony. Alternatively, the message to 'change frequency' might be actually transmitted to the receiver as part of the transmitted signal. This approach is also used in cellular phones and wireless network cards. Data about when to switch and what frequency to switch to is sent as a data packet. This isn't terribly secure as anyone with patience and the correct equipment can log the data packets and simulate the receiver. The ultimate in secure spread spectrum probably involves the modern equivalent of the 'one time pad'; a CD Rom or memory chip is used at each end; these devices contain a string of totally random noise pulses from a natural source, like solar radio noise or noise from noise diodes. A CD ROM might contain enough 'bits' for a few dozen messages; a copy would be made and the copy sent to the receiver site, usually under diplomatic protection. The CD ROM would be used for

communications, and then after each block of bits is used for a single message it's never sued again. Combined with a suitable cipher system, this sort of communication is undetectable (don't forget that the signal sounds like an increase in local noise) and even if it is detected the cipher system ensures that no one else can read the message.

And Finally.....

And finally, what did Hedy and George get for all their cleverness? Well, until recently not much. Apparently they never even received a formal thank you letter from the US Government. But earlier this year Hedy Lamarr received an award from the Electronic Frontier Foundation recognising her contributions to modern computer technology, even though it took place 50 years ago. George Antheil died before he could get the award, but at least now the contribution of the composer and the actress to modern communications has finally been recognised.