Introducing radio transmission with a simple experiment

Do you ever get frustrated with that mess of cables connecting your DVD player to your satellite dish, TV and video recorder? Did you know that you can cut those cables – and still get a signal to pass between the machines? **Alessandro Iscra**, **Maria Teresa Quaglini** and **Giuseppina Rossi** from Italy describe an experiment that will astound your students.

Stimulated by the widespread use of modern wireless devices, such as mobile phones, satellite TV receivers and wireless computer networks, many students are interested in the topic of radio transmission. Recognising this interest, we have developed both educational documents and experiments[w1], some of which use common modern wireless equipment. The project has involved many teachers working collaboratively to produce papers, multimedia activities and practical protocols.

Below, we describe a simple experiment that introduces radio transmissions to young students using a video cassette recorder (VCR) and a television (TV).

The radio transmission experiment

A VCR can transmit sound and images to a TV via either the SCART cable or the classic coaxial antenna cable. When transmitting via the coaxial cable, the VCR emulates a TV transmitter: in other words, the receiver doesn't know whether it is receiving a programme transmitted by a distant, normal transmitter or by the nearer VCR. The VCR generates a radio signal that reaches the TV via the coaxial cable. If we cut the cable, and connect the pieces of cable to two antennae, the TV will receive the audio and video signals transmitted by the VCR without any physical connection: we have achieved radio transmission. The signal transmitted is very weak, so the two antennae can be separated by only a few metres.

The following instructions should be suitable for all teachers, including those who are unfamiliar with electrical equipment. A Microsoft PowerPoint presentation[w2] and a short video clip[w3] are available online.

Image courtesy of PixelQuelle.de

Materials

- A TV
- A VCR
- Two coaxial antenna cables used to connect a VCR to a TV (with one male and one female coaxial connector). One cable will be provided with the VCR; the second, identical to the first, can be bought in a TV shop, or constructed from materials (the coaxial cable and the connectors) bought in an electrical goods shop.
- A metal grid (optional)

A spectrum analyser, a classical directional antenna and a coaxial cable: three very important devices used in radio transmission experiments

A homemade condenser, built by students from Liceo Scientifico Nicoloso da Recco (Recco, Genoa, Italy), is used to show that a variable electric field generates a magnetic field

Methods

Step 1. Connect the VCR to the TV using only the original coaxial antenna cable. A VCR is normally connected to a TV set by a thick cable joining two rectangular connectors (the SCART connectors) and/or by a thin cable joining two cylindrical connectors (the coaxial antenna cable). This latter connection is necessary to receive normal television channels, so it should be present if the TV is not just used to watch videotapes. The first thing to do is remove any other connections from the back of the VCR; the only connection should be to the TV via the coaxial cable (see right).

Step 2. Try to play a videotape using the configuration described in Step 1. This may simply require you to insert and play the videotape, then search the previously set programmes using the remote controller of the TV. Since the VCR is disconnected from the normal antenna, the TV can only receive signals transmitted by the VCR.

If no TV programme has yet been assigned to the VCR, this must be done. You may need to consult the TV instruction manual or ask a technician for help.

Step 3. Replace the original coaxial cable with the second coaxial cable, and check that the system still works. Then cut the new coaxial cable. The TV will not receive any signal.

Step 4. Remove the two pieces of the new coaxial cable from the TV and VCR and remove the external and internal insulating material along a length of about 20-30 cm (this length is not critical).

Step 5. From the un-insulated parts of the two lengths of cable, create two small antennae. Do this by exposing the inner conductor and by manipulating the outer conductor to form a single length, making the configuration shown right. See these websites[w2,w3] for further help.

Step 6. Cover the two antennae with insulating tape.

Step 7. Reconnect the lengths of cable to the TV and VCR. Maintain a distance of about 1 m between the two antennae. The TV should receive a signal from the VCR, which acts as a weak radio transmitter (see right).

Interference

If the experiment is performed outdoors or if the classroom is close to a TV transmitter, the TV may receive signals other than those from the VCR. In this case, re-tune both the TV and the VCR. First, search for a channel on which the TV receives no signal. Then tune the output channel of the VCR to the same channel. If necessary, consult the instruction manuals. Alternatively, try the experiment in another room where the interference may be less.

Cautions

Unauthorised radio transmission is strictly prohibited. Do not interpose devices such as amplifiers between the VCR and the transmitting antenna.

The propagation of electromagnetic waves

The simple experiment described here demonstrates the propagation of electromagnetic waves in air and, by placing the two antennae on either side of an obstruction (e.g. a book, a piece of aluminium foil or a wall), can be used to show how the waves penetrate objects.

The teacher can also demonstrate the polarisation of the waves by plac-

ing a metal grid between the two antennae. The waves cannot pass through the grid if the rods of the grid are parallel to the electric field vector (E in the figure right). However, the grid is penetrable if the rods are at right angles to the electric field vector.

An explanation of the observed phenomena

Radio transmission occurs when energy is carried by electromagnetic waves. This transmission may be achieved simply by applying a high-frequency voltage to a dipole antenna with a total length similar to the wavelength of the electromagnetic waves.

VCRs generate ultra-high frequency (UHF) signals in the 470-862 MHz range; the exact frequency range depends on the European channel selected[w4]. Since the wavelength (λ) is related to the frequency (f) by the simple formula $\lambda = c/f$ (where c is the speed of light), the wavelength is in the range of 0.35-0.63 m, requiring a small antenna.

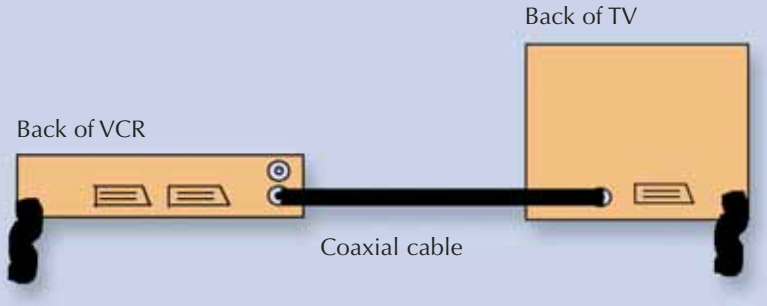
Electromagnetic waves generated by the dipole antenna are linearly polarised. The direction of the electric field (E in the figure right) is parallel to the antenna.

Web references

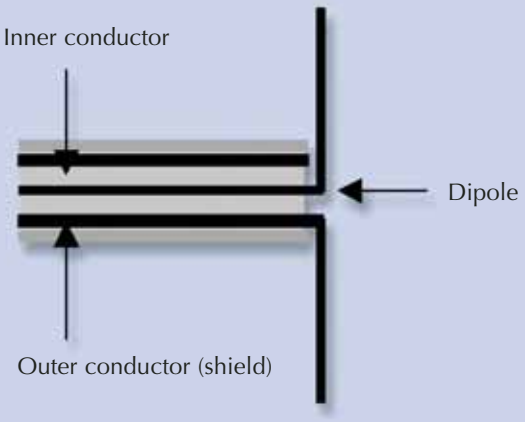
w1 - *Radio Transmissions Experiments for Educational Purposes* from a network of Italian schools: www.iscra.net/radio_educational

w2 - *How to Make a Simple Radiotransmission by Using a Videorecorder and a TV-receiver*, a PowerPoint presentation from Luisa Bove, Alessandro Iscra and Giuseppina Rossi: www.iscra.net/radio_educational/english/englishvcr.ppt

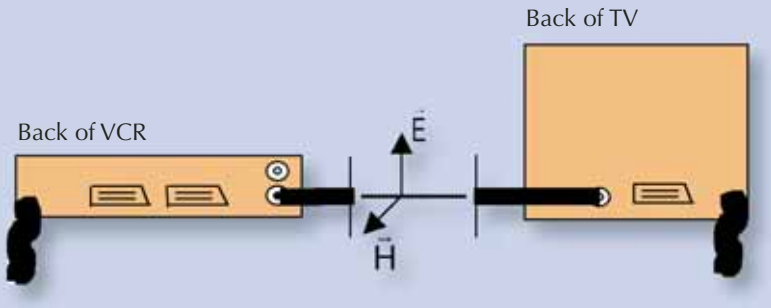
w3 - *Transmitting from a Videorecorder*, from some students of IIS "Caramuel" in Vigevano (Italy): www.iscra.net/radio_educational/english/englishvcrclip.mpg



The VCR connected to the TV using only the coaxial cable



A dipole antenna formed from a length of coaxial cable



Radio transmission and polarisation of the electromagnetic waves: E represents the electric field vector and H, the magnetic field vector. The dotted line represents the direction of propagation

BACKGROUND

A related event

The schools involved in this project recently organised a public event about the scientific, technical and social aspects of electromagnetic fields. During this event, seven projects were presented to visitors by the school students.

The event was supported by Consorzio Elettra 2000[w5], which organised a national contest – Campi Elettromagnetici e Società (Electromagnetic Fields and Society) – to stimulate secondary schools to develop projects to communicate the social aspects of electromagnetism. Consorzio Elettra 2000 provided the instruments necessary to measure the electric and magnetic fields. More details about this event are available online[w6].

The seven school projects also took part in the national contest, with one of them winning a trip to Rome.

w4 - TV Channel, CATV and FM Broadcast Frequencies from ARRL, the national association for amateur radio in the USA: www.arrl.org/tis/info/catv-ch.html

w5 - The Consorzio Elettra 2000 website: www.elettra2000.it (the Italian website links to an English version)

w6 - The website of the public event organised by the schools involved in this project: www.iscra.net/eta (only in Italian)

Resources

A more analytical approach to these experiments can be found on the following websites:

A Simple Approach to Radio Transmissions by Alessandro Iscra and Maria Teresa Quaglini: www.iscra.net/radio_educational/english/englishradiocom.ppt

Radio Transmissions by Catia Fina, Alessandro Iscra and Maria Teresa Quaglini: www.iscra.net/radio_educational/english/radiotransmissions.doc

REVIEW

This article describes an easy to prepare and interesting physics experiment to show wireless electromagnetism. Both the simple theoretical and practical aspects are covered.

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Students at the IIS "Deambrosis-Natta" testing electromagnetic hazards associated with hand-held radio devices

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